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TRANSLATION

NONLINEAR APERTURE CORRECTION

By
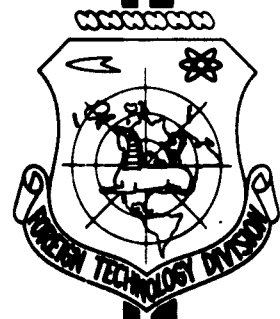
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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

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NONLINEAR APERTURE CORRECTION

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Nonlinear Aperture Correction

by

G.V.Braude; I.N.Isayeva

Discussed is a method of aperture correction, which can be called a method of
nonlinear aperture correction, equivalent in its action to the distribution of the
signal into several levels with corresponding to each level, lying near the lever of
the black, incident frequency characteristic with its equivalent frequency band, and
to each one of the levels, lying near the level of white, -frequency characteristic,
having an ascend with its degree of aperture correction.

Correction of linear distortions of the TV tract, especially the so-called aper-
ture correction leads.   As is known, to a rise in the level of fluctuation inter-
ferences in the TV tract. The degree of aperture correction and the gain in image legi-
bility connected with it is limited first of all by the increase in fluctuation
interferences.

Foreign literature has published a report[1] in which is introduced a method of
combatting the above mentioned limitation. This method consists in breaking up the
TV signal into two levels, "from black to gray " and "from gray to white", with individual
amplification of these two levels in two amplification channels, in one of which
"from black to gray " no aperture correction is introduced, and in the second one,
"from gray to white " the correction is introduced with subsequent combination of
signals from these two amplification channels. The fluctuation interferences increase
thanks to aperture correction only in luminous points of the image, where the inter-
ference effect of fluctuation interferences is particularly high. Image clearness

of dark details is lower than at an ordinary system of aperture corrections, which, however/

has no substantial effect on the general visual perception of clearness of the entire

image thanks to the low resolving power of the eye at poor illuminations.

The system, proposed in report [1] was reproduced by us and tested. These tests

showed that in dividing the signal into two levels only the effect of improving the

quality of the image , offered by the dividing system, is small and cannot

justify the greater complexity and difficulty in adjusting the system. It can be assum-

ed that the division of the signal into a greater number of levels with degree of aper-

ture correction corres;onding to each level would give a greater effect, but it would

lead to an even greater, practically nonpermissible complexity of the system.

The circuit of the corrector,formulated by the method of nonlinear aperture correc-

tion, is shown in fig.1.

If we do not consider the nonlinear circuits contained in this system, circuits

serving for the obtainment of a definite amplitude characteristic of individual parts

of the corrector, then it will be analogous to the system of differential aperture

correction, described in report [2] .

In plate circuit of tube L_1 of the system is cut in a circuit consisting of three

parallel branches: parasitic intercascade capacitance C_0, plate resistance R and sub-

sequent LC-of circuit. The voltage from this circuit is transmitted to the grid of

tube L_3 of the system. On the other hand, the voltage from auti-induction of the L

circuit, proportional to the second derivative of the input signal (v),is transmitted with

the aid of tuve L_4, which amplifies this voltage and transforms its phase ,to grid

of tube L_5 adding this voltage with a certain proportionality/coefficient with the

voltage , taken from the circuit in the general anode circuit of L_3 and L_5 tubes.

Self-induction of the L circuit is shunted by a resistance T_{sh}, attenuating natural

oscillations of a parasitic circuit, formed by this self-induction and input parasi-

tic capacitance C_4 of L_4 tube. The magnitude of this resistance is deter-

mined by formula

$$R_{\scriptscriptstyle M} = V\frac{L}{2C_{\scriptscriptstyle O}}. \qquad (1)$$

When the circuit parameters are subjected to optimum frequency characteristic, presented in form of $C = 3C_o$ and $R = 8\frac{\sqrt{9 \ L}}{C}$, the described system realizes a practically ideal aperture correction without phase distortions within limits of frequency band from zero to $\omega_{gr} = \frac{1}{\sqrt{LC}}$ in accordance with the law $\alpha = 1 + a\delta^a$, where $\delta = \frac{\omega}{\omega_{gr}}$ - relative frequency, a-correction coefficient, presented in form of $a = n\frac{S_5}{S_3} - 1$, where n - amplification factor of tube L_4, S_5- curvature of tube L_5, S_3- curvature of tube L_3.
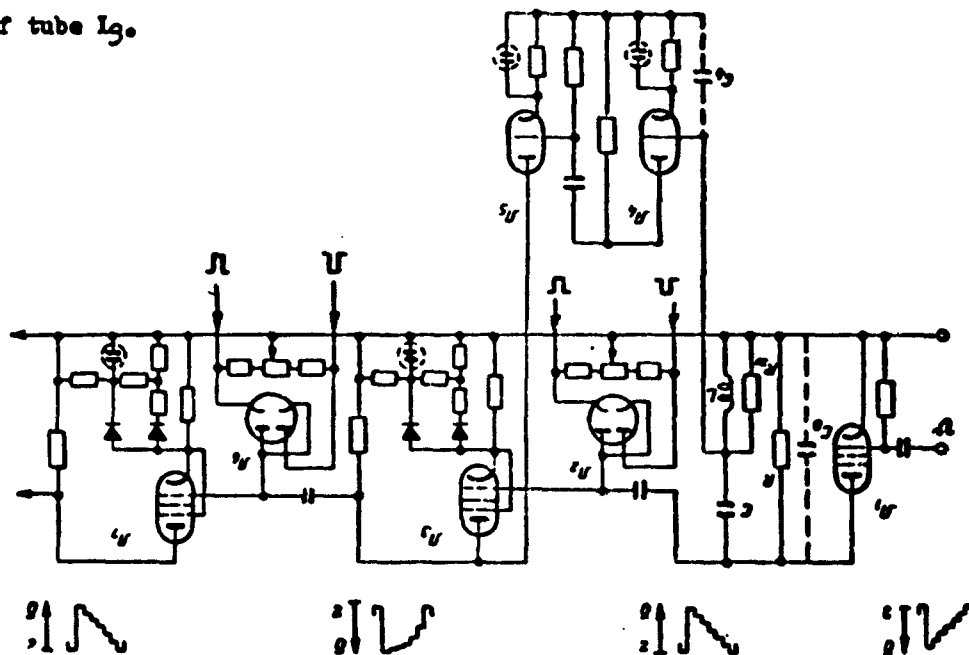

Fig. 1. Scematic of the corrector

The expression given above for the coefficient a is valid for the discussed system of aperture correction and when considering the nonlinear circuits contained in the system, if under tube curvature we keep in mind its differential curvature in the corresponding point of tube's amplitude characteristic.

In the cathode circuit of tube L_3 is connected a system of crystal diodes and re-sistors, which   forms by a known method a nonlinear resistance. decreasing

with the rise in   potential of grid of tube L_3 in such a way, that the dependence of the plate current of this tube upon the potential of its grid, amplitude characteristic of tube, acquires the form, shown in fig.2, analogous to the one which is necessary for correction of gamma-characteristic of a receiving TV tube at a directed video signal (from black to white), designated in fig.1. The curvature of this dependence-differential curvature S_3 - decreases when changing over from black level to white level.

The necessary binding of the black level on the grid of tube L_3 is realized by the known controllable system of binding with the aid of a double diode L_2.
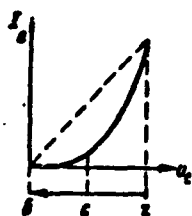

Fig.2. Dependence $I_a = f(U_c)$

Upon a change in the differential curvature S_3 it will be followed by a change in coefficient a. At a black level, when the value S_3 is maximum, the value a is minimum. At very high values S_3 the coefficient a may acquire a value, close to - 1. In this case the frequency characeristic of the corrector will have the form of an incident curve $a = 1 - \delta^2$, acquiring the value 0 at $\delta = 1$, i.e. at $\omega = \frac{1}{\sqrt{LC}}$. At a distance from the black level, when value S_3 begins decreasing, the value of the coefficient will rise, and at a value $S_{30} = nS_5$ - the coefficient a will acquire zero value. The frequency characteristic of the corrector will have the form of a horizontal straight line $a = 1$.

When approaching the white level, at further reduction in differential curvature S_3, the coefficient a, acquiring a positive value ,will rise, reaching maximum value at the white level, where differential curvature S_3 acquires minimum value. There will be a maximum rise in frequency characteristic of the aperture corrector:

$$a = 1 + a_{\text{макс}} \delta^2, \text{ где } a_{\text{макс}} = n \frac{S_5}{S_{\text{5 мин}}} - 1. \qquad (2)$$

In this way, the nonlinearity of the amplitude characteristic of tube L_3, entering the channel of the basic signal of the aperture corrector (aperture type compensator),

leads to the fact, that to each one of the signal levels, situated between the black

level and the level of the signal, corresponding to differential curvature S_{3_0},

corresponds an incident frequency characteritic with its equivalent frequency band,

and to each of the signal levels, situated between the level, corresponding to dif-

ferential curvature S_{3_0}, and the white level, corresponds a frequency characteristic

with its degree of rise - degree of aperture correction.

The level of fluctuation interferences will be correspondingly minimum at the

black level and will reach maximum at the white level.

The described aperture corrector will bring in a certain nonlinearity into the

TV tract. This nonlinearity, in spite of the fact that it is analogous to the one,

which is necessary for the correction of gamma-characteristics of a receiving TV tube, but

cannot serve for the correction of this gamma-characteristic, because the form of the

nonlinearity of the basic cha$_n$nel of the aperture corrector is determined not by the

condition of optimum gamma-characteristic of the TV channel , but by the condition

of optimum   suppression of fluctuation interferences near the black level

at optimum visual perception of image clearness. In order to obtain simultaneously

an optimum gamma characteristic of the TV channel in sequence with the described

aperture corrector , is connected a cascade of gamma-corrections, built around tubes

L_6, L_7. The action of tube L_7 is analogous to the action of tube L_3 in the channel of

the basic signal of the aperture corrector, but it brings in into the video signal

a nonlinearity of another sign , because the direction of the video signal on the

grid of tube L_7 is opposite the direction of the video signal on the grid of tube L_3

In the special case, when the entire arrangement is faced with the requirement

of linearity of amplitude characteristic, the cascade of gamma correction should

bring in a nonlinearity, reverse to the one, brought in by the basic channel of the

aperture corrector. Gamma of the entire arrangement will be equal to one. At a

variation in nonlinearity of the gamma-correction cascade, gamma of the entire arrange-

ment may be obtained greater than or smaller than one.

The entire arrangement at gamma, equal to one, appears to be an arrangement of

nonlinear aperture correction in the sense of a nonlinear dependence of the coefficient

of aperture correction a upon the level of the video signal.

To more sharply narrow the frequency band for video signal levels, situated near

the black level, into the plate circuit of one of the amplification cascades to the

described aperture corrector is connected a circuit, similar to the C_0RLC circuit,

tuned to the very same or somewhat higher boundary frequency $\omega_{bound\,1} \geqslant \omega_{band}$.

The frequency characteristic of the nonlinear aperture corrector together with its

amplification cascade at the black level approaches the form of alpha $= (1 - \frac{\omega^2}{\omega^2_{bound\,1}})$

$\times (1 - \frac{\omega^2}{\omega^2_{band}})$, and at the while level it is presented in form of

$$a = \left(1 - \frac{\omega^2}{\omega^2_{rp1}}\right)\left(1 + a_{макс}\frac{\omega^2}{\omega^2_{rp}}\right) \qquad (3)$$

a   б
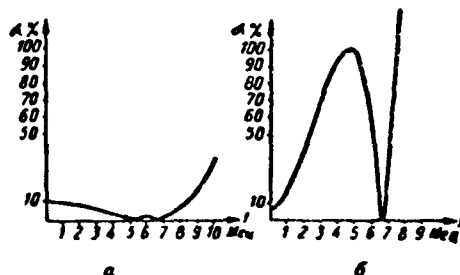
Fig.3.Theoretical frequency characteristics

In fig.3,a is given a frequency characteristics graph

$$a = \left(1 - \frac{\omega^2}{\omega^2_{rp1}}\right)\left(1 - \frac{\omega^2}{\omega^2_{rp}}\right) \qquad (4)$$

at $f_{bound} = 5$ mc and $f_{bound\,1} = 6,7$ mc $(\omega = 2\pi f)$.

In fig.3,b is given a frequency characteristics graph

$$a = \left(1 - \frac{\omega^2}{\omega^2_{rp1}}\right)\left(1 + a_{макс}\frac{\omega^2}{\omega^2_{rp}}\right) \qquad (5)$$

ate the very same values of boundary frequencies and $a_{max} = 27.$

If we should not consider the rise of the frequency   characteristic

beyond the limits of boundary   frequency of 6,7 mc. cut around

by the general frequency characteristic of the TV tract, then the first graph represents

and incident frequency characteristic with equivalent frequency band of the order

of 3.5 mc, and the second graph represents a frequency characteristic, the initial and

center sections of which have a rise, the form of which is practically determined.

by the second multiple of the frequency characteristic expression

$$\alpha = \left(1 - \frac{\omega^2}{\omega_{rp1}^2}\right)\left(1 + a_{\text{макс}}\frac{\omega^2}{\omega_{rp}^2}\right). \qquad (6)$$

The form of the last section of the graph is predominantly affected by the

first multiple of the expression of the frequency characteristic, thanks to

which the rise in frequency characteristic is being more and more slowed down, and the

frequency characteristic, reaching maximum (a = 10) at a frequency of 4.9 mc, after which

it drops sharply.

The frequency characteristics, corresponding to various levels of video signal ,

situated between black and white levels , are situated between the above mentioned

graphs. It should be pointed out, that on the ascending as well as on the descending

sections of the frequency characteristics there are practically no phase distortions,

because the above described C_oRLC circuit has a phase characteristic, which within

the limits of the frequency band ranging from zero to $\omega\sqrt{\frac{1}{LC}}$ deviates from the

linear law by not more than $5°$, and within the limits of frequencies ranging from

zero to $\omega = 2\sqrt{\frac{1}{LC}}$ it deviates from the linear law by not more than $18°$.

It is interesting to compare the above described system of nonlinear aperture

corrections with one of the possible systems of combining aperture and gamma correc-

tions. Ordinarily are used in series connected aperture and gamma-correction systems

whereby the aperture correction system is connected to a gamma-correction system. In se-

me instances the aperture correction system is connected after preliminary gamma-correc-

tion.

It is also possible to have a scheme of parallel-connection of aperture and gamma

corrections, as shown in fig.4, when gamma correction is made only in the basic channel

of the aperture corrector,constructed by the method of combining the basic signal

and the signal of the second derivative. Such an arrangement of combining aperture
and gamma corrections was tested during the development of a correction block for
the video signal of a TV relay system[3] , but it was rejected in view of greater
frames (repeats) of TV images, which have been received at this arrangement.
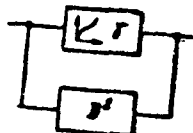

Fig.4.Scheme of parallel connection
of aperture and gamma corrections.

In can easily be shown, that the parallel
system, in this case, when gamma correction
is made of the TV receiving tube only,
appears to be a partial incomplete case of
nonlinear aperture correction. In this case there is also a nonlinear amplitude char-
acteristic of the channel of the basic signal of aperture corrector, the curvature
of which drops   during the   change over from black to white level, but the
degree of this nonlinearity is insufficient to obtain a noticeable effect in reducing
the visibility of fluctuation interferences in the black zone and in the gray zone
in particular. But there should be no TV image distortions of frame type (repeats).
In case when gamma correction is made not only in the receiving TV tube (in black
zone) but also in the transmission TV tube (in white zone) and the general amplitude
characteristic of the gamma corrector has the form of (as shown in fig.5) the above men-
tioned image distortions are possible. The fact is, the nonlinearity of the channel
of the basic signal of the aperture corrector will in this case lead to a reduction
in clearness in the white zone, since the curvature of the amplitude characteristic
grows during transition from the gray to the white level. But upon the attainment
of the necessary clearness in the white zone a recorrection is necessary in the gray
zone, causing blips in the transient characteristic, which do lead to frame type image
distortions (repeats). Similar effects
in the above described nonlinear aperture
corrector (see fig.1),naturally, do
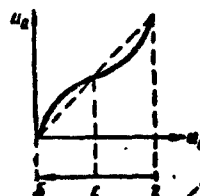not take place even in the case,when the

Fig.5. Amplitude characteristic of
gamma-corrector

gamma correction cascade contained in it is used for gamma correction of the trans
mitting TV tube (in white zone).

To experimentally investigate and test the effectiveness of nonlinear aperture
correction was constructed an intermediate amplifier,which includes: nonlinear aperture
corrector,constructed in accordance with the schematic in fig.1., amplification stage

to aperture corrector, to the plate circuit of which is cut in a circuit,similar
to the C_oRLC circuit of the nonlinear aperture corrector, and elements, inherent for
an ordinary intermediate amplifier, serving for the formation of blanking pulses,etc.
The entire principal arrangement of this intermediate amplifier is shown in fig.6.

Tubes L_3 L_{4a} L_{4b} L_5 L_6 L_7 L_8 of this system correspond to tubes L_1L_4 L_5 L_2 L_3
L_6 L_7 of the system shown in fig.1. of the nonlinear aperture corrector. Tubes L_{1a}
L_{2a} L_{2b} represent conventional video amplifier stages. Tube L_{1b} represents an above
described aplification stage,to the plate circuit of which is connected a circuit,
similar to a C_oRLC circuit of a nonlinear aperture corrector. Tubes L_{14a} L_{14b} consti-
tute an amplifier of horizontal sync pulses, serving to control the binding of the
black level (built around tubes L_5 L_7). Tubes L_{13a} L_{13b} constitute the amplifier
of blanking pulses ,introduced into the plate circuit of tube L_8 and then limited by
crystal diodes.

The level of limitation of blanking signal is controlled by the change in value
of positive voltage on the diode plate, connected in series with anode resistor
of tube L_8, and on the cathode of the diode,connected in parallel to this resistor.
Tube L_9 represents a video amplifier stage, in which with the aid of changing the
magnitude of cathode resistance is realized control of the output value of the video
signal; control of the input value of the video signal is realized as usually from
the control desk.

Tubes L_{10} L_{11} L_{12} represent output cathode followers of intermediate amplifier,
serving for the transmission of the video signal to the linear amplifier and to video
control devices. Controlling the degree of aperture correction (HF-rise) is done
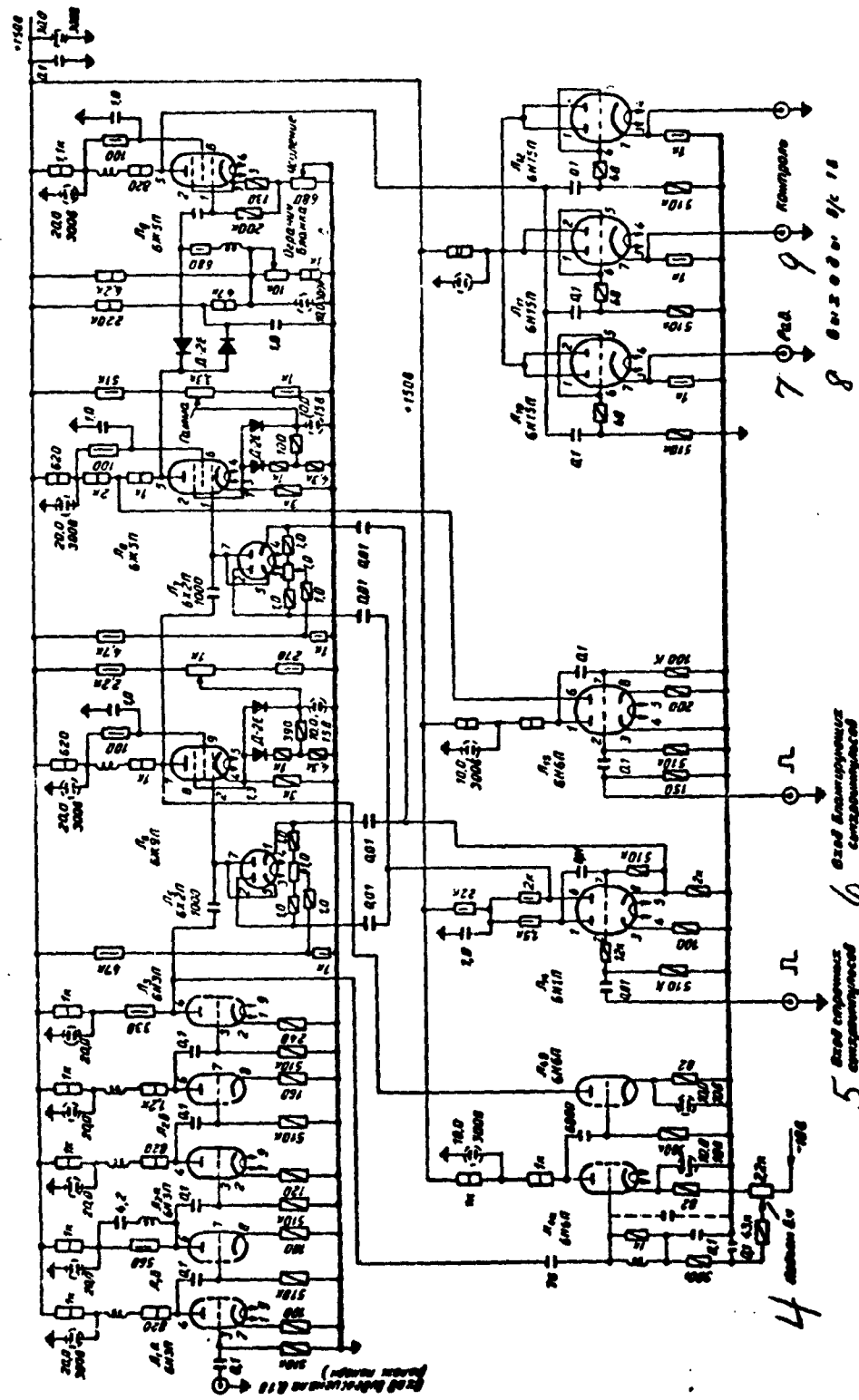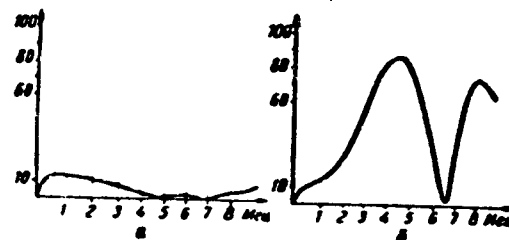
Fig. 6. Schematic of intermediate amplifier with nonlinear aperture correction; 1-input of video signal
0.18 (polar position); 2-limiting blank; 3-amplification; 4-HF-rise; 5-input of horisontal syno pulses;
6-input of blanking syno pulses; 7-radio; 8-control; 9-outputs

by changing the negative bias on the grid of tube L_{4a}. Controlling the degree of nonlinearity of the channel of basic aperture corrector signal is done by changing the value of positive voltages on the cathodes of crystal diodes, connected into the cathode circuit of tube L_6. In this way is regulated the nonlinearity of the gamma corrector ,built around tube L_8.

In fig.7a and 7b are shown experimentally plotted (on ICHEB-57) graphs of frequency characteristics of this intermediate amplifier, corresponding to black (a) and white (b) levels. These characteristics by their form correspond fully to the theoretically calculated frequency characteristics of the device, shown in fig.3a and 3b.

The rise in frequency characteristics to beyond the limits of the second boundary frequency - 6,7 mc, determinable by the circuit in the plate circuit of tube L_{1b}. as already mentioned,is clipped by the general frequency characteristic of the TV

Fig.7.Experimental frequency characteristics

tract. But, keeping in mind the necessity of observing a TV image in the equipment room of the TV-center, the equipment of which, including also the video control devices, ordinarily have a much wider band of frequencies, than the general frequency band of the TV-tract, for the purpose of obtaining a proper idea about the nature of the image at the receiving end of the entire TV tract to the input of the intermediate amplifier was attached a low frequency filter, clipping the frequencies, lying above a frequency of 6 mc. The schematic of such a filter is shown in fig.8a. This filter was designed and constructed by the method,described by [4] so that at a band pass of 6 mc with a irregularity of 0.1 db the damping on a 6.5 mc frequency should be equal - 20 db.

Experimentally plotted frequency characteristics and delay time characteristics $\gamma = \frac{d\upsilon}{d\omega}$ of this filter are shown in fig.8,b and c^1.

1.This filter was designed and constructed by engr.L.A.Levashova

Although phase distortions on frequencies, close to boundary, in such a filter are quite great, this is of no sigificant importance, because in the given zone of frequencies the frequency characteristic of the very intermediate amplifier with nonlinear aperture correction has already a greated drop and the level of spectral components of the video signal in this range of frequencies, is very small, even at a larger extent of aperture correction, taking place at the white level.

In fig.9 (a_1, a_2, a_3) are shown the plotted in this way amplitude characteristics of   the cascade built around tube L_6 (of basic signal channel) of nonlinear aperture corrector, plotted with the aid of a "step generator " at various nonlinearity degrees of this cascade. The lower stages adhering to black level, are here more or less stretched, and the upper stages, adhering to the white level, more or less compressed.

In fig.9.(b_1, b_2, b_3) have been plotted amplitude characteristics of tube L_8 of the gamma corrector , intended for correcting linearity of aperture corrector and for the obtainemnt of the given gamma of the entire installation. The linear amplitude characteristic of the entire installation is obtained approximately by combining the nonlinearity of the aperture corrector, corresponding to fig. 9,a_2 and the nonlinearity of gamma corrector, corresponding to fig.9, b_3.
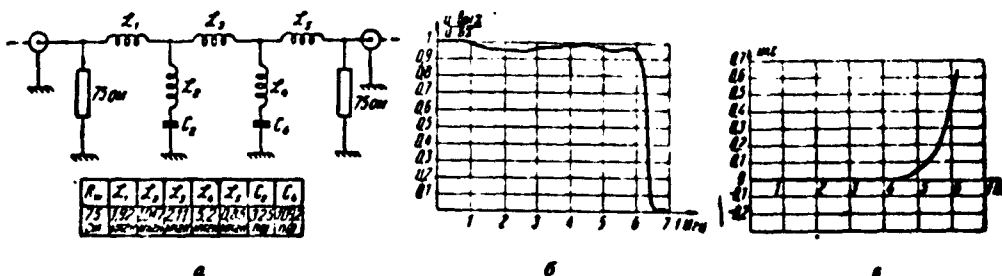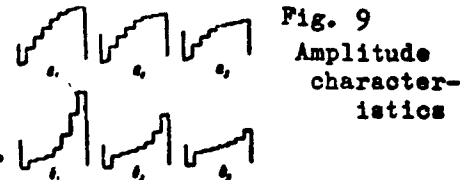

Fig.8.Schematic of the 6 mc filter (a)its frequency characteristic (b) and time delay characteristic (c).

The above described intermediate amplifier with nonlinear aperture correction

was tested in a vidicon motion picture channel of the Moscow TV center. To make a comparison was tested also the intermediate amplifier with in-series combining the linear aperture corrector and gamma corrector.

Testing the intermediate amplifier with linear aperture corrector showed, that combined application of ordinary linear aperture correction with gamma-correction cannot raise the quality of the image because of the sharp increase in fluctuation interferences during the introduction of aperture and gamma corrections as well. And in a normal vidicon motion picture channel, employed by the Moscow TV-center, in which there is no gamma correction and only linear aperture correction is used, the fluctuation interferences, particularly noticeable in black and gray zones, do not give the possibility od employing higher degrees of aperture correction,necessary for the obtainment of an image of greater clearness.

Fig. 9
Amplitude characteristics

Tests of the above experimental intermediate amplifier showed, that the introduction of a nonlinear aperture correction, at a greater degree of nonlinearity, substantially raises the quality of the TV image , increasing the number of brightness gradations and improving the clearness of the image. At a sharp reduction in fluctuation inter ferences in the black and gray zones- practical disappearance of same , drop in image

clearness in dark and gray places of the image in real subjects of various plan was practically unnoticeable. At the same time the image clearness in bright spots of the image has risen sharply and in spite that the/ fluctuation interferences in the bright spots are becoming noticeable, they had an ordered nature in form of a screen corresponding to a frequency of 5 mc. (frequency with frequency characteristic maximum of the device at the white level), which interferes very little with the observation of the image.

It can be assumed that the use in a preliminary amplifier of a complex system of an anti-interference correction[5, 6] with cut out frequency of the order

of 5 mc should in these conditions sharply reduce the visibility of the above men-

tioned interference-screen and additionally improve the quality of the TV image.

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